

Eyes Based Electric Wheelchair Control System

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Abstract—The Eye Blink Controlled Assistive System with Health Monitoring using ESP32 is an Internet of Things (IoT)-based embedded solution designed to assist individuals with limited mobility by enabling device control through eye blink patterns while simultaneously monitoring vital health parameters. The system integrates an infrared (IR) eye blink sensor, MAX30102 pulse oximeter, temperature sensor, and ESP32 microcontroller to create an intelligent and responsive assistive interface. The IR sensor continuously detects eye states (open/closed), and the ESP32 processes these signals to determine blink duration and frequency. Based on predefined patterns, control commands such as forward, backward, left, right, and stop are generated. These commands are transmitted via an embedded web server hosted on the ESP32, allowing external devices such as wheelchairs or robotic systems to retrieve commands using HTTP requests in JSON format. In addition, the system performs real-time health monitoring by measuring heart rate (BPM), blood oxygen saturation (SpO₂), and body temperature. The collected data is formatted and served through a web API for remote access. The proposed system offers a low-cost, portable, and efficient solution for assistive healthcare and smart rehabilitation applications.

Index Terms—ESP32, IoT, Eye Blink Detection, Assistive System, Health Monitoring, MAX30102, Embedded Systems

I. INTRODUCTION

Assistive technologies play a crucial role in improving the quality of life for individuals with physical disabilities by enabling them to interact with their surroundings more independently. Conventional control systems typically rely on manual inputs such as switches, touch interfaces, or voice commands, which may not be suitable for individuals suffering from severe motor impairments or paralysis. As a result, there is an increasing demand for alternative

human-machine interaction techniques that are simple, cost-effective, reliable, and non-invasive.

Among various approaches, eye blink detection has emerged as an efficient and practical solution for assistive control systems. Eye movements require minimal physical effort and remain functional even in patients with significant mobility limitations. By detecting intentional blink patterns using sensors, it becomes possible to translate these signals into control commands for operating electronic devices, thereby enhancing user independence and accessibility. In addition to assistive control, continuous health monitoring is equally important for ensuring patient safety and enabling timely medical intervention. Monitoring vital parameters such as heart rate, blood oxygen levels, and body temperature provides valuable insights into the patient's health condition and helps caregivers make informed decisions.

In this context, the integration of Internet of Things (IoT) technology offers significant advantages, including real-time data acquisition, remote monitoring, and efficient data management. This paper presents an IoT-based assistive system that combines eye blink-controlled device operation with real-time health monitoring using the ESP32 microcontroller. The proposed system aims to provide a user-friendly, efficient, and intelligent solution to support individuals with limited mobility while simultaneously ensuring continuous health supervision.

II. LITERATURE REVIEW

Assistive mobility systems have gained significant attention in recent years, particularly for individuals with severe physical disabilities. Researchers have explored various control mechanisms such as pressure sensors, eye tracking, biosensors, and artificial

intelligence techniques to improve wheelchair usability and independence.

González-Cely et al. (2023) proposed a real-time wheelchair controller using polymer optical fiber (POF)-based pressure sensors. The system detects neck movements through pressure variations and employs fuzzy logic for control. This approach is non-invasive and reliable, but it still requires partial body movement, limiting its applicability for completely immobilized users.

Amer et al. (2021) developed an eye-gaze-based wheelchair control system. Their design focuses on simplicity and affordability, making it accessible to a wider population. However, eye-tracking systems often require cameras and complex image processing, which can increase system cost and computational requirements.

Tesfamikael et al. (2021) introduced an image segmentation-based eye-tracking wheelchair system. The proposed model achieved approximately 90% accuracy with reduced response time, demonstrating improved real-time performance. Despite these advantages, such systems may be sensitive to lighting conditions and require calibration.

Wang et al. (2021) presented a wheelchair control system using flexible hydrogel biosensors combined with wavelet transform and support vector machine (WT-SVM) algorithms. This approach enhances signal accuracy and reliability but involves complex sensor fabrication and processing techniques, which may increase implementation cost.

Rajkumar et al. (2022) developed a cost-effective eye-motion-controlled wheelchair achieving over 94% accuracy. Their system demonstrates the feasibility of using simple eye movement detection for practical applications, though it may still face challenges in distinguishing involuntary eye movements.

Rexha et al. (2023) explored the integration of brain-computer interface (BCI) signals using Open-BCI technology for wheelchair control. This method provides advanced control capabilities but is expensive and requires complex signal processing, making it less suitable for low-cost implementations.

Luo et al. (2021) proposed a human-computer interaction system based on intelligent eye movement recognition. By extracting pupil features and tracking eye trajectories, the system improves control precision. However, it depends heavily on image processing techniques, which may introduce latency.

Xu et al. (2023) implemented a deep learning-based eye-gaze controlled wheelchair. Their system improves motion smoothness and reduces sudden acceleration using AI models. While effective, deep learning approaches require high computational power and training datasets.

Higa et al. (2023) introduced a hybrid deep learning model combining 1D-CNN and LSTM for estimating user intentions. This approach addresses issues such as unintended commands (Midas touch problem) and enhances user experience. However, system complexity and cost remain challenges.

Dahmani et al. (2020) developed a low-cost eye-tracking system for motorized wheelchair control. The study emphasizes affordability and accessibility while maintaining acceptable performance, making it suitable for real-world applications.

III. PROPOSED SYSTEM

The proposed system is an Eye Blink Controlled Assistive System with Health Monitoring using ESP32, designed to assist physically challenged individuals in controlling devices and monitoring their health conditions in real time.

Phase 1: Eye Blink Detection

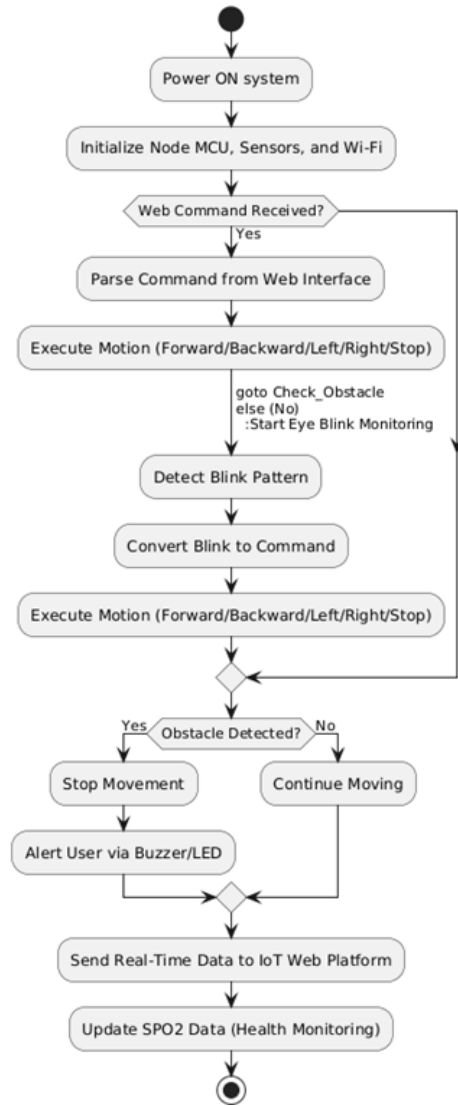
In this phase, an infrared (IR) eye blink sensor continuously monitors the user's eye movements. When the user blinks, the sensor detects the change in reflection and converts it into an electrical signal. The system distinguishes between eye open and eye closed states and further differentiates intentional and unintentional blinks based on timing and pattern recognition.

Phase 2: Signal Processing

The detected signals are transmitted to the ESP32 microcontroller, where they are processed in real time. The ESP32 analyzes the input signals and identifies

predefined blink patterns such as single blink, double blink, and long blink. Each of these patterns is mapped to a specific command for system operation.

Eye-Based Electric Wheelchair Control System Flowchart



Phase 3: Device Control Based on the processed blink patterns, the ESP32 sends appropriate control signals to output devices through a motor driver or relay module. For example, a single blink may initiate forward movement or turn on a device, a double blink may change direction, and a long blink may stop movement or turn off a device. This phase enables complete hands-free control of assistive devices such as wheelchairs or home appliances.

Phase 4: Health Monitoring In this phase, the system continuously monitors the user’s vital health parameters. The MAX30102 sensor is used to measure

heart rate and blood oxygen saturation (SpO2), while a temperature sensor records the user’s body temperature. These readings are collected and processed by the ESP32 at regular intervals.

Phase 5: IoT Data Transmission The processed health data and system status are transmitted to an IoT platform using the ESP32’s built-in Wi-Fi capability. The data is uploaded to cloud servers such as Firebase or Thing Speak, enabling real-time access and storage of information.

Phase 6: Remote Monitoring and Alerts In this phase, caregivers or medical professionals can remotely monitor the patient’s condition through a web or mobile interface. They can view vital parameters such as heart rate, SpO2, and temperature, track system activity, and receive alerts in case of abnormal readings, ensuring timely medical response.

Phase 7: Feedback and Safety Finally, the system provides feedback to the user through visual and auditory indicators such as LEDs and a buzzer, which indicate system status and alerts. Additionally, an optional ultrasonic sensor can be integrated to detect obstacles and enhance safety during device operation.

IV. IMPLEMENTATION AND METHODOLOGY

A. Methodology

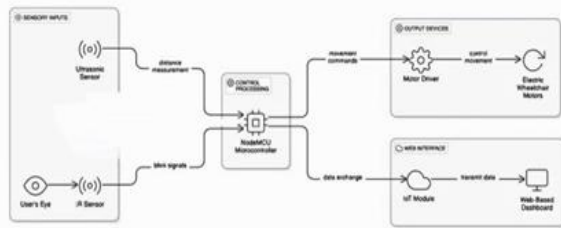
The proposed Eye Blink Controlled Assistive System with Health Monitoring is developed using a structured methodology that integrates signal acquisition, processing, control execution, and IoT-based monitoring. The system is designed to operate in real time with high reliability and minimal user effort. Initially, the infrared (IR) sensor is used to detect eye blink patterns, which serve as the primary input for system control. Simultaneously, physiological parameters such as heart rate, blood oxygen saturation (SpO2), and body temperature are acquired using appropriate sensors. The collected signals are then processed by the ESP32 microcontroller, which interprets blink patterns and converts them into corresponding control commands.

The processed data is utilized for two main purposes: controlling external devices (such as motors or relays) and transmitting health-related information to an IoT platform. A feedback mechanism using LEDs and a

buzzer is incorporated to provide real-time system status to the user.

B. System Architecture

The system architecture is divided into three functional layers to ensure efficient operation and modular design. The input layer consists of components such as the IR eye blink sensor, MAX30102 pulse oximeter, and temperature sensor, which are responsible for acquiring user input and collecting physiological data. The processing layer is centered around the ESP32 microcontroller, which acts as the main control unit by performing signal processing, decision-making, and communication tasks. The output layer includes motor drivers, actuators, buzzer, LED indicators, and the IoT platform, which are used to execute control commands and display the system status. This layered architecture enables smooth data flow, improves system reliability, and simplifies overall design and implementation.



C. Hardware Implementation

The hardware implementation involves interfacing various sensors and output devices with the ESP32 microcontroller. The IR sensor is positioned to accurately detect eye blinks and transmit signals to the controller. The MAX30102 sensor is used to measure heart rate and SpO2 levels, while the temperature sensor monitors body temperature. A motor driver (L298N/L293D) is employed to control actuators such as DC motors for movement or device switching. An optional ultrasonic sensor can be integrated for obstacle detection to enhance safety. Additionally, LEDs and a buzzer are used to provide visual and auditory feedback, respectively. All components are connected through GPIO pins of the ESP32, ensuring proper signal transmission and synchronization.

D. Software Implementation

The software for the proposed system is developed using the Arduino IDE with embedded C/C++ programming, and the firmware is designed to perform

continuous monitoring and control operations. It is responsible for detecting and classifying eye blink patterns, acquiring and processing health sensor data such as heart rate, SpO2, and temperature, and executing control commands through motor drivers. Additionally, the software establishes Wi-Fi connectivity using the ESP32 to enable IoT communication and ensures the transmission of real-time data to a cloud platform for remote monitoring. The program operates in a continuous loop structure, allowing uninterrupted system functionality and real-time response to user inputs and sensor data.

E. Algorithm

The working algorithm of the system is as follows:

1. Initialize the ESP32 microcontroller and sensors
2. Continuously monitor eye blink signals using the IR sensor
3. Detect and classify blink patterns (single, double, long)
4. Map the detected pattern to a predefined control command
5. Execute the command using motor drivers or relays
6. Acquire health parameters (heart rate, SpO2, temperature)
7. Upload sensor data to the IoT platform via Wi-Fi
8. Check for abnormal health conditions and generate alerts if necessary
9. Provide feedback using LED and buzzer
10. Repeat the process continuously

F. Flow of Operation

The system follows a continuous operational flow consisting of input acquisition, signal processing, decision-making, execution, and feedback. The integration of IoT ensures that all relevant data is updated in real time for remote monitoring.

V. RESULT AND EVALUATION

A. Experimental Setup

The proposed Eye Blink Controlled Assistive System with Health Monitoring was implemented using an ESP32 microcontroller integrated with an IR eye blink sensor, MAX30102 pulse oximeter, and temperature sensor. The system was tested under different environmental conditions to evaluate its performance, reliability, and accuracy. The testing was carried out in

both indoor and semi-controlled environments with varying lighting conditions. Multiple users participated to analyze system response, blink detection accuracy, and health monitoring performance.

B. Performance Metrics

The system performance was evaluated based on several key parameters, including eye blink detection accuracy, response time, health parameter accuracy, IoT data transmission efficiency, and power consumption. These metrics were considered to assess the overall effectiveness, reliability, and real-time performance of the proposed assistive system.

C. Results

The experimental results demonstrate the effective performance of the proposed system across multiple parameters. The IR eye blink sensor successfully detected blink patterns with high accuracy, achieving approximately 95–98% under normal lighting conditions, although slight variations were observed under extreme lighting such as direct sunlight. The system exhibited a fast response time, with an average delay of about 0.5 to 0.8 seconds between blink detection and corresponding action, ensuring smooth and real-time operation. In terms of health monitoring, the MAX30102 sensor provided reliable measurements of heart rate and SpO2 levels with an accuracy of approximately $\pm 2\%$, while the temperature sensor delivered consistent readings within acceptable medical limits. The IoT communication performance was also efficient, as the ESP32 transmitted real-time data to the cloud platform with minimal delay, maintaining stable connectivity throughout operation. Additionally, the system demonstrated low power consumption, allowing it to operate continuously for several hours using battery power. Overall, the results indicate that the system is reliable, responsive, and suitable for real-time assistive applications.

D. Evaluation

The overall evaluation of the system indicates that it performs effectively as an assistive solution for individuals with limited mobility. The eye blink detection mechanism proved to be reliable and easy to use, requiring minimal user effort. The integration of health monitoring enhances the system's functionality by providing continuous medical data. IoT

connectivity further improves usability by enabling remote monitoring and timely intervention by caregivers.

VI. CONCLUSION AND FUTURE SCOPE

CONCLUSION

In this paper, an Eye Blink Controlled Assistive System with Health Monitoring using ESP32 has been successfully designed and implemented to support individuals with severe physical disabilities. The system provides a hands-free control mechanism using eye blink detection, enabling users to operate assistive devices with minimal effort.

The integration of health monitoring sensors such as the MAX30102 and temperature sensor allows continuous tracking of vital parameters including heart rate, SpO2 levels, and body temperature. The use of the ESP32 microcontroller ensures efficient processing and seamless IoT connectivity, enabling real-time data transmission and remote monitoring.

Experimental results demonstrate that the system achieves high accuracy in blink detection, fast response time, and reliable health monitoring. The IoT-based communication further enhances the system by allowing caregivers to monitor the user's condition remotely and respond promptly in case of emergencies. Overall, the proposed system offers a cost-effective, user-friendly, and reliable solution that improves independence, safety, and quality of life for physically challenged individuals.

VII. FUTURE SCOPE

The proposed system can be further enhanced in several ways to improve its performance, reliability, and usability. Future developments may include the integration of advanced algorithms or machine learning techniques to improve the accuracy of eye blink detection and to effectively distinguish between voluntary and involuntary blinks under varying environmental conditions. Additional health monitoring sensors such as ECG, blood pressure, and respiration sensors can be incorporated to provide a more comprehensive analysis of the user's health status. The system can also be upgraded with advanced obstacle detection technologies like LiDAR or multiple ultrasonic sensors to ensure safer navigation in complex environments. Furthermore, the

development of a dedicated mobile application would enhance user interaction and allow easier access to real-time data and alerts. Integration of voice and gesture recognition alongside eye blink control could provide multiple input options, improving accessibility for a wider range of users. The use of artificial intelligence can enable predictive analysis and personalized assistance based on user behavior. Finally, improvements in power management and battery efficiency can extend the operational time of the system, making it more suitable for continuous real-world usage.

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